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FaNGaS: Fast Neutron Gamma Spectroscopy instrument for prompt gamma signature of inelastic scattering reactions

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Abstract: The FaNGaS instrument has been developed and constructed at the Forschungszentrum Jülich GmbH for investigation of neutron inelastic scattering reactions using the fission neutron beam SR10 at the Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM II) operated by the Technische Universität München in Garching. Prompt emitted gamma rays from excited states of irradiated elements can be used for analytical purposes.

1 Introduction

At neutron energies of around 2 MeV of the fission neutron beam SR10 the prevailing nuclear reaction in matter is inelastic scattering, (n,n$'\gamma$) with minor contributions from (n,γ), (n,p), (n,2n), and (n,α) reactions. Similar to cold neutron PGAA, the promptly emitted gamma rays from (n,n$'\gamma$) reactions can be used for chemical quantification of elements, provided a reliable data catalogue for partial and inelastic scattering cross sections is available. Building up from earlier work FaNGaS can help to create an extended data base for use of fission and 14 MeV neutrons for quantitative analysis of large and very large samples.

2 Instrument description

FaNGaS consists of a set of collimators – stacked layers of PE, B_4C and pure Pb – to reduce the beam size to a diameter of 50 mm and a well shielded electrically cooled HPGe detector (50 % rel. efficiency, 2.1 keV resolution at 1332 keV) connected to a digital spectrometer (DSPEC 50). Shielding against scattered neutrons and gamma radiation is achieved by 30 cm of PE, 1 cm of B_4C and 15 cm of ordinary lead bricks. The sample position during irradiation is 67 cm away from the detector surface. A second measurement position is located 17.2 cm from the detector surface allowing measurement of decay activity from (n,γ), (n,p), (n,2n), or (n,α) reactions from samples after irradiation (see FIG 1).

Figure 1: FaNGaS set-up with neutron collimator, gamma counting and sample positioning system in the MEDAPP bunker (picture: TU München, W. Schürmann. Also submitted to Journal of Radioanalytical and Nuclear Chemistry article ‚Prompt and delayed inelastic scattering reactions from fission neutron irradiation - first results of FaNGaS‘(JRNC-D-15-01030)).

Efficiency calibration for both positions has been achieved by measurement of calibrated radioactive sources (PTB) and a thermal irradiation of Cl (PVC) for the high energy region of the gamma spectrum. The energy distribution of the fission neutron beam of SR10 after installation of the neutron collimators has been determined by the metal foil irradiation technique using nuclear threshold reactions and unfolding software STAYSL PNNL (see FIG 2).

3 Typical applications

- Determination of partial and inelastic scattering cross section of pure elements
- Combination of delayed and prompt spectra (e.g. Actinide irradiation and measurement of fission products produced, determination of (n,f) cross sections
- Determination of elements with very high (n,γ) cross sections, such as B, Cd, Gd, etc. in large samples
- Special analytical tasks where cold neutron PGAA is limited, e.g. P in high purity SiO2

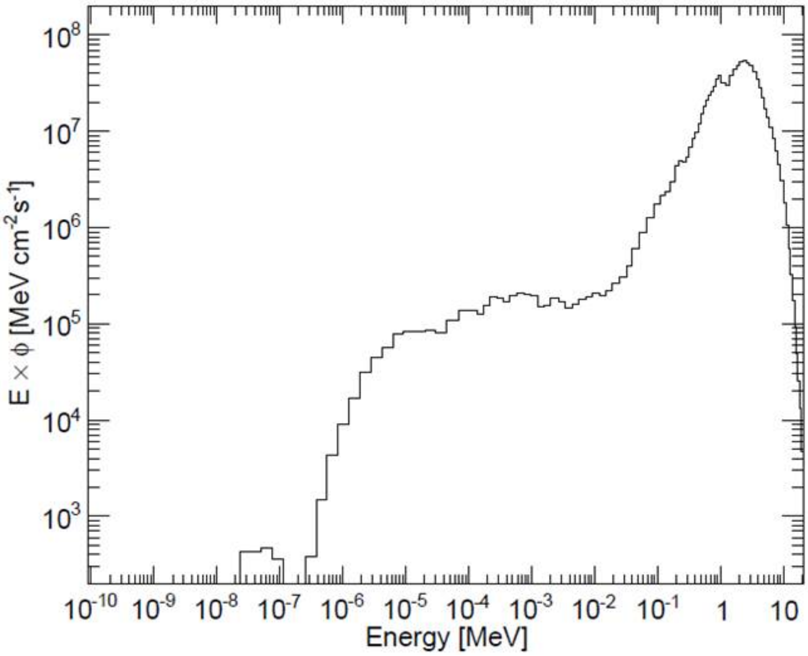

Figure 2: Neutron energy spectrum of the SR10 beam line at FRM II with FaNGaS collimators installed.

4 Technical data

4.1 Neutron source

- Converter facility at FRM II consisting of 2 plates of 93 % enriched U-235
- Two collimators of stacked PE, B_4C and Pb with total length of 101 cm in the beam line restrict the fast beam to 5 cm diameter.
- Average neutron beam energy is 2.12 $\pm$ 0.08 MeV
- Integrated neutron flux is (1.01 $\pm$ 0.042) x $10^8 cm^{-2}s^{-1}$

4.2 Detector system

- GMX50-83 n-type HPGe detector, electrically cooled, 50 % relative efficiency, 2.1 keV energy resolution at 1332 keV
- Detector shielding consisting of PE (30 cm) B_4C (1 cm) and Pb (15 cm) mounted on a steel table with wheels to make the system movable.
- DSPEC-50 spectrum acquisition, MAESTRO and GAMMA-Vision evaluation software (ORTEC) and HYPERMET-PC

4.3 Sample environment

- Maximum sample size is 50 x 50 x 50 mm, normally 25 x 25 x 0.5 mm metal foils are irradiated
- Samples for irradiation are located 548 cm from neutron source position and 67 cm from detector end cap.
- Small samples can be counted after irradiation at 17.2 cm from detector end cap

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